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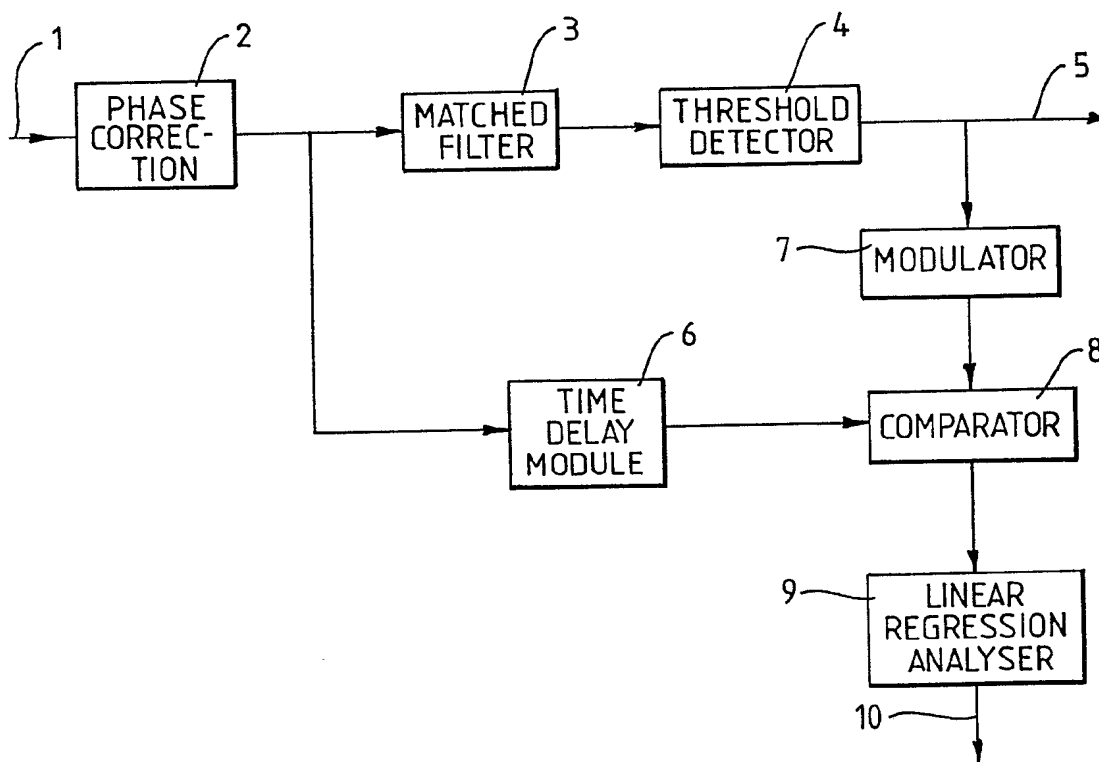
(52) UK CL (Edition L)
H4P PAPD

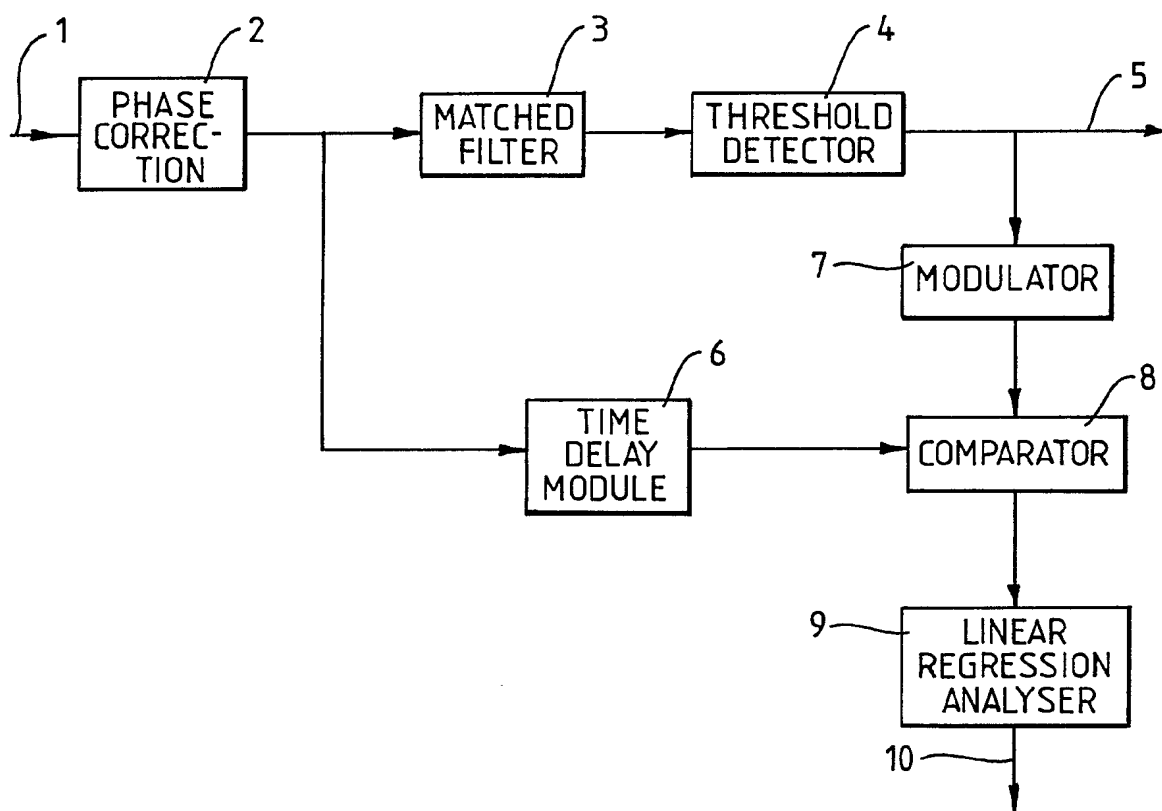
(56) Documents cited
EP 0059415 A1

(58) Field of search
UK CL (Edition K) **H4P PAL PAPD PAPM PAPS PAPX**
INT CL⁵ **H04L 27/22**

(54) **Demodulator with frequency error correction**

(57) A demodulator for use in radiotelephone communication receivers and in particular, for demodulating digital data from GMSK phase modulated carriers operating in a time division multiple access (TDMA) format. The demodulator compensates for frequency errors in the receiver's local oscillator by remodulating (7) the threshold-detected (4) bit stream (5) and comparing (8) the phase of the remodulated signal with a time-delayed version (6) of the base-band signal. From the resulting phase error signal the frequency error is computed by linear regression analysis (9). The frequency error is used as a frequency correction signal (10) for the local oscillator.





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DEMODULATOR

This invention relates to digital radiotelephone communication systems and in particular to demodulators which form part of said systems' receiver circuitry.

Known radiotelephone communication systems operate at UHF and over a multiplicity of frequency channels. Multi-channelling can be achieved by a variety of methods. These are, for example, frequency division multiple access (FDMA), time division multiple access (TDMA) or a combination of the two.

In one known type of radiotelephone communication system to which this invention is particularly applicable, a plurality of radio frequencies is employed to provide appropriate allocation of speech communication channels. Each frequency is time-divided into time frames which are further sub-divided into time slots (or bursts).

Analogue speech signals from a handset are digitised into a bit stream by one of several known methods, such as pulse code modulation (pcm) for example and then modulated onto a carrier by a coherent method such as Gaussian minimum shift keying (GMSK).

In order to recover speech data from the carrier, a demodulator is required.

An object of this invention is to provide a demodulator having means for compensating for frequency errors which are introduced via the receiver circuitry's local oscillator. These

errors arise, particularly in low-cost receivers, because of the inaccuracy of the reference source used in such receivers. A typical low-cost reference source, driving a local oscillator, may have a frequency accuracy of 10 ppm. For a local oscillator running at 900 MHz, for example this results in a frequency error (or offset) of 9 KHz. If the error is left uncorrected, errors occur in the demodulator output because of uncompensated phase rotation of the base-band signal.

The invention comprises a demodulator for recovering digital data from a base-band signal, said base-band signal being corrupted by a frequency error, in which the demodulator comprises:

means for aligning the phase of the base-band signal with that of a stored reference to produce a phase-aligned base-band signal;

means for extracting from said phase-aligned base-band signal, a digital bit stream;

means for remodulating the digital bit stream; means for comparing in phase the resulting remodulated signal with a time-delayed version of said phase-aligned base-band signal to produce a phase error signal; and

means for determining said frequency error from the phase error signal.

The present invention thus achieves the above object by making use of demodulated digital data from one received burst to estimate the frequency error and then correcting for the next burst.

An embodiment of the invention will now be described, by way of example only, with reference to the drawing which is a block diagram of a demodulator in accordance with the invention.

A GMSK-modulated RF signal in TDMA burst format and carrying pulse-coded data is mixed down to DC in the first stage of a radio receiver (not shown).

The resulting base-band signal on line 1 is aligned in phase (with respect to a reference signal) by a phase alignment circuit 2. Phase alignment is necessary because the coherent demodulator structure which follows the phase alignment circuit 2 uses phase information relative to a set of reference axes, to which a burst must be aligned.

The signal is then passed through a matched filter 3 and threshold detector 4 to recover the received bit stream on line 5. Circuitry for estimating frequency error comprises a time delay module 6, modulator 7, phase comparator 8 and linear regression analyser 9.

The base-band signal on line 1 is demodulated as follows. Firstly, the phase alignment circuit 2 performs a correlation operation on a training sequence carried by the received RF signal and a local stored reference training sequence. The reference training sequence is stored in the phase alignment circuit 2. Said correlation operation provides an estimate of the mean phase difference between the stored reference and the base-band signal. This estimate is then used to correct the base-band signal which is then applied to the input of the matched filter 3.

The matched filter 3 and threshold detector 4 function in a conventional manner in order to extract a bit stream from the phase-aligned base-band signal. I.e., the filter 3 optimises the signal to noise ratio by removing excess noise from the base-band signal, and the detector 4 evaluates the sign of said signal to determine whether a '0' or a '1' is present.

The output of the threshold detector 4 however may contain errors resulting from inaccuracy of the reference source in the receiver's first stage. It is thus important to correct the inaccuracy of the reference source.

To achieve this, the bit stream appearing on line 5 is modulated by a conventional GMSK modulator 7. This operates by filtering the bit stream with a Gaussian low pass filter, then applying the resultant signal to a base-band phase modulator with a modulation index of 0.5. The resulting, remodulated signal contains no frequency error because it has not passed through the first stage of the receiver.

The resulting, remodulated signal is then compared (in phase) with a time-delayed version of the incoming, phase-aligned base-band signal by the phase comparator 8. Said base-band signal is delayed by a predetermined amount by passing through the time delay module 6. This time delay is

introduced in order to account for time delays within the matched filter 3, threshold detector 4 and modulator 7.

The output of the phase comparator 8 is the phase error as a function of position within a received burst. The comparator achieves this result by subtracting the phase of the modulated signal at the output of the modulator 7 from the phase of the delayed base-band signal appearing at the output of the delay module 6.

From the phase error, the frequency error is derived by a linear regression analysis, carried out by the analyser 9. Said analysis evaluates the frequency error which represents the best least mean squares fit for the phase error as a function of time, across the entire burst. The resultant, calculated frequency error signal appearing on line 10 is fed as a correction signal to the reference source in the receiver's first stage. For example, the correction signal could be used to adjust the voltage on a reference voltage controlled oscillator. Thus the frequency is adjusted before the arrival of the next received burst.

Provided the number of bit errors in the recovered data is relatively low (eg 1 in 50 or better) then this frequency error estimate is much less affected by noise than an alternative technique which evaluates rate of change of phase error across the training sequence. For a training sequence which, typically, comprises 26 out of 148 bits, the accuracy of this alternative method is much affected by noise.

CLAIMS

1. A demodulator for recovering digital data from a base-band signal, said base-band signal being corrupted by a frequency error, in which the demodulator comprises:

means for aligning the phase of the base-band signal with that of a stored reference to produce a phase-aligned base-band signal;

means for extracting, from said phase-aligned base-band signal, a digital bit stream;

means for remodulating the digital bit stream; means for comparing in phase the resulting remodulated signal with a time-delayed version of said phase-aligned base-band signal to produce a phase error signal; and

means for determining said frequency error from the phase error signal

2. A demodulator according to claim 1 in which the base-band signal is derived from an RF carrier modulated by Gaussian minimum shift keying.

3. A demodulator according to either preceding claim in which the base-band signal is derived from a time division multiple access (TDMA) signal.

4. A demodulator according to any preceding claim in which the means for aligning the phase of the base-band signal with that of a stored reference comprises a correlator.

5. A demodulator according to any preceding claim in which the means for extracting a digital bit stream comprises a matched filter and a threshold detector.

6. A demodulator according to claim 2 in which the means for remodulating the digital bit stream is a Gaussian minimum shift keying modulator.

7. A demodulator according to any preceding claim in which the means for determining the frequency error comprises a linear regression analyser.

8. A method of demodulating a base-band signal generated by a radio receiver for recovery of digital data therefrom, said base-band signal being corrupted by a frequency offset, the method comprising the steps of:

aligning the phase of the base-band signal with that of a stored reference to produce a phase-aligned base-band signal;

extracting from said base-band signal, by threshold detection, a digital bit stream;

remodulating the digital bit stream;

comparing, in phase, the resulting remodulated signal with a time-delayed version of said phase-aligned base-band signal to produce a phase error signal;

determining by linear regression analysis from the phase error signal, a frequency error signal;

applying said frequency error signal to said radio receiver whereby said frequency offset is compensated.

9. A method of demodulating a base-band signal according to claim 8 in which the base-band signal is derived from an RF carrier modulated by Gaussian minimum shift keying.
10. A method of demodulating a base-band signal according to claim 8 or claim 9 in which the base-band signal is derived from a time division multiple access (TDMA) signal.
11. A demodulator substantially as hereinbefore described with reference to the drawing.
12. A method of demodulating a base-band signal substantially as hereinbefore described with reference to the drawing.

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Patents Act 1977

Examiner's report to the Comptroller under
Section 17 (The Search Report)

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Relevant Technical fields

(i) UK Cl (Edition K) H4P (PAL, PAPD, PAPM, PAPS, PAPX)

Search Examiner

K WILLIAMS

(ii) Int CL (Edition 5) H04L 27/22

Databases (see over)

(i) UK Patent Office

Date of Search

10 APRIL 1992

(ii)

Documents considered relevant following a search in respect of claims

1-10

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	EP 0059415 A1 (NIPPON ELECTRIC) see whole specification and US 4525676	1,8

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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